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An Analysis of Technical Progress and Efficiency in U.S. Food Industries

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Abstract

Using a non-parametric data envelope analysis, we measure the total factor productivity (TFP) and its efficiency components for 48 U.S. food manufacturing industries during 1960-94 at the 4-digit SIC level. Although food manufacturing is labor intensive, labor use declined over the study period and the annual increase in output came from increased use of capital accompanied by consequent rise in energy use. It was found that across all industries and over the entire period, productivity grew at an annual rate of 1.1 percent, which was much lower than those observed in the agricultural production sector or the entire U.S. manufacturing sector. Efficiency gains and losses across various food-industry groups were mostly mutually offsetting and efficiency change did not have noticeable impact on overall TFP growth, and technological progress was the main contributor to productivity improvement.

Key words: technical progress, efficiency index, food industries, data envelop analysis, productivity

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1. Introduction

Food and tobacco manufacturing industries in the United States have been undergoing important changes over the past few decades, mostly due to increasing industrialization, globalization, and technological changes. In such a rapidly evolving economic environment, it is important to know which industries are performing efficiently and its implications. Understanding and measurement of productivity is also important because of the fact that productivity growth is a major source of overall economic growth and welfare improvement of both consumers and producers. In fact, productivity improvement will lead to lower prices and higher consumer welfare unless the entire productivity gain is retained by producers in a non-competitive market environment. Technical advance and technical efficiency improvements are two key factors to overall productivity growth which are associated with different sources and may need different policies to address them. It is, therefore, important to decompose total productivity growth into these two components: technical efficiency change and technological change.

Food processing is the largest manufacturing sector in the U.S. in terms of number of industries identified by the 4-digit SIC (Standard Industrial Classification) code and plays an important role in the U.S. economy. In terms of food alone, its presence begins at the farm level and extends to the consumer's plate. The food manufacturing sector has experienced numerous innovations and transformations in the production, processing, and marketing technology over the years. Changing consumer demand and demographics, changes in relative input prices and their uses, increasing trade, and related factors have impacted the structure of the food industry (Goodwin and Brester, 1995; Senauer, Asp, and Kinsey, 1991). Impact of such factors on the structure of the food industries would inevitably affect their productivity and performance.

Measurement of productivity and efficiency in the agricultural production and food processing sectors in the United States has been the focus of numerous studies (e.g., Morrison, 1999; Gopinath and Roe, 1997; Ball et al., 1997; Huffman and Evenson, 1992; Chavas and Cox, 1994; Pardey et al., 1997; and Capalbo and Antle, 1988), with most studies emphasizing on the production agriculture. Although most of these studies have ignored the issues of productivity and efficiency in the U.S. food manufacturing sector, those studies that shed some light on these critical issues use highly aggregated data, generally at the 2-digit SIC level. A notable exception to this literature was the empirical work by Heien (1983) who computed multi-factor productivity measures at a disaggregated level for a selected number of food industries. Heien’s work had severe limitations, such as failure to include capital inputs and inconsistencies in terms of input definitions. Productivity and efficiency analyses conducted at the highly aggregated 2-digit SIC level, on the other hand, are less realistic and fail to provide a deeper insight into the technical performance of the food manufacturing industries. For instance, these highly aggregated studies do not show a breakdown of efficiency components mentioned earlier that were responsible for changes in the total factor productivity (TFP) in the U.S. food manufacturing sector.

Using disaggregated data at the 4-digit SIC level for over 35 years, we examine the patterns of productivity and efficiency changes in the 48 U.S. food-processing industries (Appendix table 1). Specifically, we estimate total factor productivity and isolate technological (or technical) advance and technical efficiency change for each of these 48 industries using non-parametric data envelope analysis (DEA). One advantage of the DEA method over parametric methods is that it does not depend on functional specification of the unknown production technology. The rest of the paper is organized as follows: Section 2 describes the methodology involved in obtaining total factor productivity measure and its decomposition into technical efficiency change and technological change. Section 3 presents a brief description of the data and presents the empirical results, followed by the Discussion and Conclusion section.

2. Productivity and Efficiency Measurement

In this study, productivity change in each of the 48 food industries is calculated as the geometric mean of two Malmquist indexes. Introduced by Caves et al. (1982), the (output-based) Malmquist productivity index is defined as the ratio of two (output) distance functions. Distance functions are functional representations of multiple-output, multiple-input technology which requires data only on input and output quantities. This index, therefore, is a *primal* measure of productivity change that, in contrast to the Törnqvist or Fisher Index, does not require cost or revenue share for aggregation purposes and yet is capable of measuring total factor productivity growth in a multi-input, multi-output setting.

Caves et al. (1982) show that under certain conditions, the Törnqvst index is equivalent to the geometric mean of two Malmquist output productivity indexes[1]. In its original form, Törnqvst index does not allow for the decomposition of productivity growth into changes in performance and changes in technology since it assumes that production is always efficient. The same applies to the growth-accounting approach to measurement of total factor productivity. Thus, some of the widely used productivity indexes, such the Törnqvist or Fisher index, may lead to biased results unless there is evidence that an industry identified as efficient (or inefficient) is truly so.

This paper follows the approach developed and implemented by, among others, Färe et al. (1985), Färe (1988), Färe et al. (1989), Färe et al. (1994), and Färe and Grosskopf (1996) which explicitly recognizes that improvements in technical efficiency and technical progress are two important factors in productivity growth. The measurement of productivity change by the Malmquist index, as is done in this study, is based on the concept of output distance function. Following Shephard (1970) or Färe (1988), output distance function at time t can be defined on the technology $S^t = \left\{\left(x^t, y^t\right): x^t \text{ can produce } \mathrm{y}^t\right\}$as

$$D_0^t\left(x^t, y^t\right) = \inf\left\{q : \left(x^t, y^t/q\right) \in S^t\right\} \qquad (1)$$

which is the reciprocal of the *maximum* proportional expansion of the output vector $\mathbf{y}^t$, given input vector x^t. In the special case of a single output, the output distance function can be written as

$$D_0^t\left(x^t, y^t\right) = y^t \big/ F\left(x^t\right) \qquad (2)$$

where $F\left(x^t\right)$ is the production function defined by

$$F\left(x^t\right) = \max\left\{y^t : \left(x^t, y^t\right) \in S^t\right\} \qquad (3)$$

If outputs are weakly disposable, i.e., $D_0^t\left(x^t, y^t\right) \in S^t$ and $0 \le q \le 1$ then $D_0^t\left(x^t, q\, y^t\right) \in S^t$, then $D_0^t\left(x^t, y^t\right) \le 1$ if and only if $\left(x^t, y^t\right) \in S^t$ in which case the output distance function completely characterizes the technology. The

[1] The conditions include technical efficiency, allocative efficiency and that the underlying technology is translog with all second-order terms being equal over time. The Malmquist index, however, does not require any assumption with respect to efficiency and functional form.

output distance function (1) is homogeneous of degree +1 in outputs implying that $D_0^t\left(x^t, q\,y^t\right) = q\,D\left(x^t, y^t\right)$ and is the reciprocal of the output-based Farrell (1957) measure of technical efficiency.

Following Färe et al. (1989), the Caves et al. (1982) definition of Malmquist productivity index can be defined as the geometric mean of two quotients of output distance functions:

$$M_0\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \left(\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)} \frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right)^{\frac{1}{2}} \tag{4}$$

The index thus employs distance functions from two different periods or technologies, $D_0^t(\cdot,\cdot)$ and $D_0^{t+1}(\cdot,\cdot)$, and two pairs of input-output vectors, $\left(x^t, y^t\right)$ and $\left(x^{t+1}, y^{t+1}\right)$. Caves et al. (1982) assume that $D_0^t\left(x^t, y^t\right) = D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)$ implying that own-period observations are technically efficient in the sense of Farrell (1957). The approach used in this paper does not impose such restriction *a priori* and explicitly allows for technical inefficiency.

As has been demonstrated by Färe et al. (1989), the Malmquist index (4) can be decomposed into two components, namely technical efficiency change (EFFCH) and technical change (TECHCH), defined as:

$$M_0\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)} \times \left[\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)} \frac{D_0^t\left(x^t, y^t\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right]^{\frac{1}{2}} \tag{5}$$

where the ratio outside the square bracket measures the change in relative efficiency (i.e., the change in how far observed production is from maximum potential production) between years t and $t+1$. The geometric mean of the two ratios inside the square bracket captures the shift in technology between the two periods evaluated at $\mathbf{x^t}$, and $\mathbf{x^{t+1}}$, that is,

$$EFFCH = \frac{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_0^t\left(x^t, y^t\right)} \tag{6}$$

$$TECHCH = \left[\frac{D_0^t\left(x^{t+1}, y^{t+1}\right)}{D_0^{t+1}\left(x^{t+1}, y^{t+1}\right)} \frac{D_0^t\left(x^t, y^t\right)}{D_0^{t+1}\left(x^t, y^t\right)}\right]^{\frac{1}{2}}. \tag{7}$$

To further illustrate the Malmquist index, consider Figure 1 where the technologies corresponding to period t and t+1 are drawn as S^t and S^{t+1}. The input-output vectors $\left(x^t, y^t\right)$ and $\left(x^{t+1}, y^{t+1}\right)$ are both feasible in their own periods, but $\left(x^{t+1}, y^{t+1}\right)$ does not belong to S^t. In the figure, $D_0^{t+1}\left(x^{t+1}, y^{t+1}\right) = Oa/Ob$ and $D_0^t\left(x^t, y^t\right) = Od/Oe$.

Thus the term outside the square bracket in (5) equals:

$$EFFCH = \frac{Oa}{Ob}\frac{Oe}{Od} \tag{8}$$

Similarly, the term inside the square bracket in (5) is given by

$$TECHCH = \left[\frac{Oa}{Oc}\frac{Ob}{Oa}\frac{Od}{Oe}\frac{Of}{Od}\right]^{\frac{1}{2}} = \left[\frac{Ob}{Oc}\frac{Of}{Oe}\right]^{\frac{1}{2}} \tag{9}$$

The last expression shows that the ratios of the terms inside square bracket in (5) measure shifts in technology at input levels $\mathbf{x}^{\mathbf{t}}$ and $\mathbf{x}^{\mathbf{t+1}}$, respectively. This measures technical change as the geometric mean of two shifts, which is of the same form as Fisher Ideal index.

Although, in principle, one may calculate Malmquist productivity index under different returns to scale assumptions, this study calculates the index relative to a constant returns to scale(CRS) technology which is decomposed into efficiency change and technical progress. Since under CRS, scale of operation is irrelevant, entire efficiency change is due to technical efficiency change. However, if variable returns to scale (VRS) is allowed (i.e., technology that exhibits first increasing, then constant, and finally decreasing returns) efficiency change could come from the use of inefficient scale of operation (identified as Scale Efficiency) as well as from pure technical inefficiency. An enhanced decomposition of the Malmquist index, as developed in Färe et al. (1994), that recognizes this issue is implemented in this study. In this decomposition, the efficiency-change component calculated relative to CRS technology is decomposed into a pure efficiency change (PECH) and a scale efficiency change (SCCH) that reflects the use of sub-optimal scale of operation by firms.

The concept of scale efficiency is presented in Figure 2 with two technologies, i.e., constant returns to scale (CRS) and variable returns to scale (VRS). The VRS technology in this figure is reflected by the (single input-single output) production function showing at first increasing, then constant, and then decreasing returns to scale. The scale efficiency measure corresponding to input $\mathbf{x}^{\mathbf{t}}$ is given by

$$Scale \text{ Efficiency} = \frac{(\text{Oa}/Ob)}{(\text{Oa}/Oc)} = \frac{Oc}{Ob} \quad (10)$$

We can include scale efficiency for periods t and $t+1$ in the measure of efficiency change (i.e., (6)) as follows:

$$EFFCH = \frac{S_0^t\left(x^t, y^t\right)}{S_0^{t+1}\left(x^{t+1}, y^{t+1}\right)} \frac{D_0^{t+1}\left(x^{t+1}, y^{t+1} \,|VRS\right)}{D_0^t\left(x^t, y^t \,|VRS\right)} \text{, where} \quad (11)$$

$$Scale\ Efficiency\ Change = SCCH = \frac{S_0^t\left(x^t, y^t\right)}{S_0^{t+1}\left(x^{t+1}, y^{t+1}\right)} \text{, and}$$

$$Pure\ Efficiency\ Change = PECH = \frac{D_0^{t+1}\left(x^{t+1}, y^{t+1} \,|VRS\right)}{D_0^t\left(x^t, y^t \,|VRS\right)}$$

So, the enhance decomposition of Malmquist Productivity Index (M_0) implemented in this study can be written as:

$$Malmquist\ Poductivity\ Index = EFFCH \times TECHCH = SCCH \times PECH \times TECHCH \quad (12)$$

3. Data and Results

This section reports the estimated productivity growth and its various components for 48 food industry groups (at 4-digit 1987 SIC classification) over the period 1960-1994. Data for the analysis came from the NBER (National Bureau of Economic Research) Manufacturing Productivity Database. This database was compiled at NBER using data from various government data sources, such as Census Bureau’s Annual Survey of Manufactures and Census of Manufactures. Aggregate output of each sector is measured by the value of shipment. Labor is defined in production worker hours. The capital stock data from the database are real capital stock (in 1987 dollar), and includes both plant (real structures capital) and equipment capital. It also provides data on materials and energy inputs, both defined in real terms (in 1987 dollar).

Summary of average annual growth rates in output and inputs are reported in Table 1. As is seen in Table 1, on the average output of 48 industries grew at an annual rate of 1.5 percent over the sample period. Annual growth rate of output varied from a high of 5.7 percent in the bread, cake and related products industry (SIC 2015) to a minimum of –5.2 percent in the canned and cured fish and seafoods industry (SIC 2091). Annual growth rate (across all 48 industries) of labor input was –0.99 percent while materials and energy inputs grew at 0.5 percent and

1.4 percent, respectively. Capital use increased by an annual average rate of 2.9 percent across all 48 industries, with fresh or frozen prepared fish industry (SIC 2092) registering the highest annual growth rate of 8.2 percent.

The nonparametric method of productivity measurement used in the analysis constructs a best-practice frontier from the data in the sample and compares individual industry with this frontier. Since the basic component of Malmquist index is related to measures of technical efficiency, we first report the estimated efficiency of the 48 industries for selected years in Table 2 in terms of CRS, VRS and Scale. It should be noted that reported efficiency index EFFCH measures efficiency relative to a CRS technology. Since CRS technology is scale neutral, it is implicitly assumed in this case that all firms in all industries are operating at optimum scale of operation. Efficiency measure under VRS technology allows the possibility that inefficiency, as measured by EFFCH, may be due to firms deviating from respective optimum scale of operation (this is measured by SCCH) as well as due to pure technical inefficiency (this is measured by PECH). Thus, scale efficiency and pure technical efficiency isolate the two components that comprise the overall efficiency measure. The efficiency indexes Values of unity imply that the industry is on the best-practice frontier while values below unity imply that the industry is below the frontier or technically inefficient.

It is evident from the Table 2 that average technical efficiency (across industries) experienced noticeable decline in 1994 compared to other years for which this index was calculated. This is true irrespective of whether one uses the CRS assumption or VRS framework. Only six of the 48-industries maintained efficiency score of unity for at least two periods for which the efficiency measure was computed. Estimated pure technical efficiency measure (which allows for VRS), i.e., scale efficiency, provides similar picture. Scale efficiency scores suggest sizeable deviation from optimum scale of operation. For example, in 1994 at least half of the food industries had scale efficiency score of 0.90 or below indicating inefficient scale of operation by those industries. In a related note, Bhuyan and Lopez (1997) found that approximately one-third of the food industries were operating at decreasing returns to scale during 1972-87. Also, in 1994 the best performing industries include the meat packing plants (SIC 2011), cheese (SIC 2022), breakfast cereals (SIC 2043), chocolate and cocoa products (SIC 2066), cottonseed oil mills (SIC 2074), soft drinks (SIC 2086), canned and cured fish and seafoods (SIC 2091), and potato chips and similar snacks (SIC 2096), while the worst performing industries include dehydrated fruits, vegetables, and soups (SIC 2034), frozen fruits and vegetables (SIC 2037), rice milling (SIC 2044), raw cane sugar (SIC 2061), beet sugar (SIC 2063), salted and roasted nuts and seeds (SIC 2068), and flavoring extracts and syrups (SIC 2087).

Table 3 reports a summary of average performance of each industry over the entire 1960-94 period in terms of TFP and its component measures. [2] Since Malmquist index is multiplicative, the geometric mean is used to calculate the averages. The index is constructed in such a way that the value of the index above unity would imply TFP growth while value of the index below unity would indicate productivity regress or deterioration in performance. Looking at the bottom of Table 3, it can be observed that on average (across all industries and over the entire period) productivity grew at an annual rate of 1.1 percent. Such growth rate is much lower than those observed in the agricultural production sector (1.94 percent reported by Ball, et al.) and slightly lower than those observed for all manufacturing industries combined (1.3 percent reported by Gullickson, 1995). However, our productivity estimates are substantially higher than the negligible 0.007 percent average annual growth rate estimated by Heien for selected food manufacturing industries for the 1950-77 period. Further, almost all of the productivity growth came from technical change (TECHCH) rather than improvement in efficiency, the former contributing for about 1 percent of TFP growth while the later accounted for 0.1 percent of the TFP growth (table 3). Among the 48 industries, soybean oil mills (SIC 2075) experienced the fasted TFP growth (2.8 percent per year) followed by the malt beverage (SIC 2082) and distilled and blended liquors (SIC 2085) (2.7 percent in both), and malt (SIC 2083), flavoring extracts and syrups (SIC 2087) (2.3 percent in each case). Among industries experiencing negative TFP growth (implying absolute deterioration in performance) are bread, cake and related products (SIC 2051), cookies and crackers (SIC 2052), candy and confectionaries (SIC 2064), and chocolate and cocoa products (SIC 2066) industries.

There is limited literature explaining the reasons for the overall low or sluggish productivity growth in the U.S. food manufacturing industries as well as deterioration of productivity in some industries. Lee and Schluter (1993) suggested that domestic demand expansion is the major factor behind increased output in the food processing industries. It is, however, commonly accepted that at the industry level, the domestic market for processed food is mature and thus, demand expansion need to come from foreign markets. Increasing trade among the nations provides such opportunities for U.S. food manufacturers who may need to pursue their international marketing strategies more vigorously to achieve higher growth. Economic theory suggests that inefficient firms (or industries) can not survive in the long run *unless* there is a cushion of excess profits derived from market imperfections or market power. Based on data from 1972 to 1987, Bhuyan and Lopez (1997) showed that most of food manufacturing industries had market power. We hypothesize that long-run inefficiency may have been cushioned by excess profits gained from existing market power in the U.S. food manufacturing industries. Thus, welfare loss in these industries due to the combined effect of inefficiency in production and imperfect market structure may even exceed some recent estimates (e.g., Bhuyan and Lopez, 1998).

Another important factor contributing to the productivity growth (or decline) of the U.S. food industries is the rate of technological innovation in these industries. Connor and Schiek (1997) suggested measuring the rate of technological innovations in the food industries in terms of resources allocated to research and development (R&D) activities, including R&D expenditures, and scientists and engineers employed in the industry. National Science Foundation reports that food manufacturing industries (SIC 20) spend less than 1 percent of their annual sales in R&D. Such extremely low spending on R&D by the food manufacturing firms is perhaps not surprising. Unlike tech-heavy industries, such as defense or aerospace, most of the technological innovations that occur in the food industries are limited to product and packaging variations. Moreover, industrial innovations employed in the food processing sector are generally developed elsewhere (e.g., industrial engineering) rather than within the sector.

The average performance (over the sample period) indicators reported in Table 3 show that except two industries, namely poultry slaughtering and processing (SIC 2015) and bread, cake and related products (SIC 2051) industries, the food manufacturing sector experienced some degree of technical progress (10 percent annually over 1960-94). Results also show that efficiency decline has been a drag on TFP growth. For instance, benchmarking against CRS technology, the estimated results indicate that half of the 48 food industries either experienced efficiency decline or stagnation. When a VRS technology is used as benchmark, (pure) technical efficiency declined over the years for half of the industries, while 31 of the industries experienced scale efficiency decline

Table 4 reports the estimated average annual rate of productivity and efficiency change in the 1960s, 1970s, 1980s, and 1990s. It can be seen from the table that overall efficiency remained stable over 1960-80 and declined since 1981. On the other hand, estimated technical change measure reveals that the food-processing sector

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[2] Detailed, disagreegated result for each industry for each year is available upon request from the authors.

experienced secular technological improvement of the entire 1960-94 period. The rate of technical progress hovered around 0.5 percent per year during the 1960s and 1970s, and then accelerated significantly during the 1981-94 period. Despite marked improvement in the rate of technical progress after 1980, the TFP growth rate did not show similar improvement due to efficiency declines during the same period. The tremendous number of mergers and acquisitions that took place in the food manufacturing sector during mid-1970 through the late 1980s must have impacted the productivity and efficiency in this sector. We are, however, not certain about the magnitude and direction of such impact.

The cumulated productivity and its components are reported in Table 5. It may be observed from the table that overall efficiency (average over all industries) in 1994 was only 2 percentage points higher that that in 1960 if CRS technology is the benchmark (it is only 5 percent when VRS technology is the benchmark). On the other hand, average (over all industries) technology index increased 41 percent over the same time period while Malmquist TFP index is 44 percent higher compared to those in 1960. Although efficiency gains (or lack thereof) did not contribute to the average TFP growth, it was a major drag in certain industries. For instance, despite a 40 percent total gain in technology index, the chocolate and cocoa products industry (SIC 2066) experienced a 16 percent decline in TFP due to at least 40 percent decline in efficiency. Similarly, TFP index for dry, condensed, and evaporated dairy products (SIC 2023) and vegetable oil mills-n.e.c. (SIC 2076) industries registered only a modest increase over the entire period even though these two industries had sizeable technical progress. TFP was highest for soybean oil mills (SIC 2075) that saw its output increase to more than two and a half times its output in 1960. Other significant gainers (whose output either doubled or almost doubled during the same period) are creamery butter (SIC 2021), malt beverages (SIC 2082), malt (SIC 2083), distilled and blended liquor (SIC 2085), and flavoring extracts and syrups (SIC 2087) industries.

Those industries that experienced high TFP growth also experienced significant efficiency gains. Only four of the 48 industries, namely bread, cake and related products (SIC 2051), cookies and crackers (SIC 2052), candy and other confectionaries (SIC 2064), and chocolate and cocoa products (SIC 2066) industries experienced productivity decline over the entire period. Maximum technological progress was witnessed by soybean oil mills (SIC 2075) followed by flavoring extracts and syrups (SIC 2087), fluid milk (SIC 2026), and prepared feeds (SIC 2048) industries. The slowest technical progress (excluding the two industries with technical regress) took place in cookies and crackers industry (SIC 2052) followed by candy and other confectionaries (SIC 2064) and cheese manufacturers (SIC 2022). The finding that many of the 48 food processing industries experienced significantly higher than average technical progress reveals the limitations of similar studies with highly aggregated data for those analyses are unable to uncover the important differences across industries in terms of productivity and efficiency performances. Further, the finding that many of the industries were characterized by significant technical inefficiency suggests that widely used TFP indexes in earlier studies, such the Törnqvist or Fisher index, may lead to biased results.

4. Summary and Conclusions

Using a non-parametric data envelope analysis, we measure the total factor productivity (TFP) and its efficiency components for 48 U.S. food manufacturing industries during 1960-94 at the 4-digit SIC level. Understanding and measurement of productivity is important because of the fact that productivity growth is a major source of overall economic growth and welfare improvement of both consumers and producers. Our results show that average output for the sample industries grew at an annual rate of 1.5 percent. Among the factors of production, while the labor input decreased at an annual rate of 0.99 percent, materials and energy inputs grew at 0.5 percent and 1.4 percent, respectively, and capital use increased at an average annual rate of 2.9 percent across all 48 industries. Because food manufacturing is labor intensive and the study shows labor use declined over the study period, the annual increase in output must came from increased use of capital accompanied by consequent rise in energy use.

We also found that on average, across all industries and over the entire period, productivity grew at an annual rate of 1.1 percent, which was much lower than those observed in the agricultural production sector or the entire U.S. manufacturing sector. Further, almost all of the productivity growth came from technical change rather than improvement in efficiency; the former contributing for about 1 percent of TFP growth while the later accounted for 0.1 percent of the TFP growth.). Thus, efficiency decline has been a drag on TFP growth. Efficiency gains and losses across various food-industry groups were mostly mutually offsetting and efficiency change did not have noticeable impact on overall TFP growth, and technological progress was the main contributor to productivity improvement. This highlights why similar analysis using more aggregate data (e.g., at 2-digit SIC level) or a weaker measure of productivity index (e.g., Törnqvist or Fisher index) may have failed to uncover the differences in efficiency performance across various disaggregated industries.

Although we propose some hypotheses explaining the reasons for sluggish productivity and efficiency measures, we plan to extend this study in that direction in the future.

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Table 1. Average Annual Growth Rates in Output and Inputs in the U.S. Food Manufacturing Industries, 1960-94 (percent)

Industry	Output	Labor	Materials	Energy	Capital
2011	1.010	0.990	1.008	0.999	1.017
2013	1.031	1.017	1.028	1.042	1.041
2015	1.057	1.036	1.035	1.056	1.035
2021	0.962	0.918	0.950	0.922	0.998
2022	1.041	1.016	1.046	1.039	1.053
2023	1.005	0.995	1.014	0.985	1.047
2024	1.013	0.991	1.008	1.009	1.030
2026	1.002	0.975	1.002	0.993	1.017
2032	1.018	0.996	1.010	1.015	1.026
2033	1.013	0.982	1.007	1.019	1.023
2034	1.020	1.013	1.016	1.050	1.032
2035	1.028	1.002	1.022	1.027	1.031
2037	1.041	1.020	1.032	1.051	1.049
2038	1.050	1.026	1.039	1.048	1.047
2041	1.007	0.977	0.967	1.019	1.016
2043	1.039	1.015	1.028	1.040	1.042
2044	1.023	1.002	0.980	1.076	1.064
2045	1.031	1.016	1.027	0.991	1.028
2046	1.038	0.986	1.034	1.032	1.047
2047	1.025	0.995	0.986	1.014	1.025
2048	1.024	0.990	1.019	1.020	1.018
2051	0.997	0.984	0.998	1.008	1.009
2052	1.016	1.003	1.020	1.027	1.035
2053	1.049	1.034	1.040	1.062	1.044
2061	1.014	0.993	1.012	0.981	1.026
2062	0.979	0.959	0.983	0.984	0.994
2063	1.011	0.990	1.008	1.003	1.030
2064	1.022	0.996	1.018	1.049	1.031
2066	1.014	0.998	1.003	1.016	1.052

Table 1. Continued

Industry	Output	Labor	Materials	Energy	Capital
2068	1.025	0.999	1.025	1.021	1.035
2074	0.964	0.951	0.965	0.985	0.994
2075	1.037	0.995	1.034	1.027	1.013
2076	0.965	0.938	0.957	0.980	1.010
2077	1.017	0.978	1.001	1.018	1.001
2079	1.002	0.985	1.001	0.993	1.009
2082	1.034	0.980	1.017	1.021	1.008
2083	1.003	0.972	0.959	0.980	1.010
2084	1.041	1.014	1.031	1.027	1.018
2085	1.012	0.964	0.994	0.956	1.001
2086	1.033	0.989	1.048	1.027	1.011
2087	1.040	1.000	1.017	1.003	1.018
2091	0.948	0.937	0.955	0.960	1.055
2092	1.023	1.016	1.048	1.067	1.082
2095	0.986	0.981	0.968	1.038	0.990
2096	1.003	1.006	0.967	1.021	1.066
2097	0.974	0.958	0.938	0.943	1.036
2098	1.021	1.005	1.018	1.030	1.061
2099	1.002	1.007	0.978	1.011	1.065
Mean (all industries)	**1.5**	**0.99**	**0.5**	**1.4**	**2.9**

Table 2. Technical and Scale Efficiency in U.S. Food Manufacturing Industries: Selected Years

Industry	1960			1970			1980			1994		
	EFFCH (CRS)	PECH (VRS)	SCCH	EFFCH (CRS)	PECH (VRS)	SCCH	EFFCH (CRS)	PECH (VRS)	SCCH	EFFCH (CRS)	PECH (VRS)	SCCH
2011	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2013	0.79	0.85	0.93	0.76	0.82	0.92	0.78	0.93	0.84	0.88	1.00	0.88
2015	0.31	0.33	0.96	0.41	0.52	0.80	0.56	0.71	0.79	0.80	1.00	0.80
2021	0.84	0.84	1.00	0.79	0.85	0.93	1.00	1.00	1.00	1.00	1.00	1.00
2022	0.98	0.98	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2023	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.92	0.99	0.69	0.70	0.99
2024	0.70	0.70	0.99	0.59	0.60	0.99	0.57	0.59	0.97	0.51	0.51	1.00
2026	0.75	1.00	0.75	0.65	0.95	0.68	0.74	1.00	0.74	0.58	0.92	0.63
2032	0.69	0.70	0.98	0.69	0.78	0.88	0.71	0.72	0.99	0.59	0.71	0.84
2033	0.50	0.74	0.68	0.53	0.74	0.72	0.56	0.77	0.73	0.51	0.89	0.57
2034	0.62	0.72	0.85	0.61	0.72	0.85	0.54	0.62	0.88	0.44	0.53	0.83
2035	0.64	0.66	0.98	0.69	0.70	0.99	0.72	0.73	0.98	0.58	0.59	1.00
2037	0.48	0.50	0.96	0.60	0.65	0.93	0.72	0.77	0.94	0.48	0.60	0.80
2038	0.50	0.53	0.93	0.62	0.63	0.99	0.70	0.70	1.00	0.66	0.81	0.81
2041	0.73	0.73	1.00	0.59	0.60	0.98	0.58	0.58	1.00	0.56	0.57	0.98
2043	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.84	1.00	0.84
2044	1.00	1.00	1.00	1.00	1.00	1.00	0.46	0.62	0.74	0.47	0.69	0.68
2045	0.82	1.00	0.83	0.88	0.97	0.91	0.84	0.93	0.91	0.60	0.65	0.93
2046	0.53	0.59	0.90	0.57	0.62	0.91	0.80	0.83	0.96	0.75	0.78	0.97
2047	0.52	0.55	0.96	0.59	0.59	0.99	0.69	0.70	0.98	0.70	0.87	0.81
2048	0.65	0.70	0.93	0.59	0.75	0.79	0.64	0.77	0.83	0.67	0.88	0.76
2051	0.69	1.00	0.69	0.81	1.00	0.81	0.79	1.00	0.79	0.69	1.00	0.69
2052	0.86	1.00	0.86	1.00	1.00	1.00	0.99	1.00	0.99	0.68	0.90	0.76

Table 2. Continued

Industry	1960 EFFCH (CRS)	1960 PECH (VRS)	1960 SCCH	1970 EFFCH (CRS)	1970 PECH (VRS)	1970 SCCH	1980 EFFCH (CRS)	1980 PECH (VRS)	1980 SCCH	1994 EFFCH (CRS)	1994 PECH (VRS)	1994 SCCH
2053	0.47	1.00	0.47	0.65	1.00	0.65	0.76	0.97	0.78	0.63	0.97	0.65
2061	0.56	0.77	0.73	0.57	0.75	0.76	0.45	0.57	0.79	0.47	0.54	0.87
2062	0.82	0.83	1.00	0.96	0.99	0.97	0.63	0.64	0.99	0.52	0.56	0.93
2063	0.59	0.64	0.91	0.54	0.59	0.92	0.42	0.50	0.85	0.45	0.48	0.95
2064	0.85	1.00	0.85	1.00	1.00	1.00	0.84	0.98	0.86	0.65	0.96	0.67
2066	0.99	1.00	0.99	0.76	0.83	0.91	0.79	0.80	0.98	0.66	0.70	0.94
2068	0.75	0.83	0.91	0.84	0.98	0.85	1.00	1.00	1.00	1.00	1.00	1.00
2074	0.50	0.60	0.84	0.51	0.83	0.62	0.51	0.64	0.79	0.35	0.70	0.49
2075	0.79	0.84	0.94	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2076	0.86	1.00	0.86	0.61	1.00	0.61	0.51	1.00	0.51	0.51	1.00	0.51
2077	0.38	0.49	0.78	0.44	0.49	0.89	0.44	0.50	0.88	0.54	0.59	0.92
2079	0.76	0.81	0.94	0.81	0.85	0.95	0.89	0.89	1.00	0.63	0.65	0.96
2082	0.44	0.53	0.82	0.55	0.72	0.77	0.70	0.88	0.80	0.67	1.00	0.67
2083	0.57	1.00	0.57	0.63	1.00	0.63	0.65	1.00	0.65	0.52	1.00	0.52
2084	0.66	0.96	0.69	0.66	0.81	0.82	0.74	0.76	0.98	0.53	0.56	0.95
2085	0.45	0.47	0.96	0.63	0.64	0.98	0.86	0.86	1.00	0.60	0.67	0.90
2086	0.88	1.00	0.88	0.93	1.00	0.93	0.77	1.00	0.77	0.66	1.00	0.66
2087	0.90	1.00	0.90	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2091	0.88	0.96	0.91	0.93	0.99	0.93	0.60	0.70	0.85	0.39	0.71	0.55
2092	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.99	0.99	0.99
2095	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.88	1.00	0.88
2096	1.00	1.00	1.00	0.79	0.79	1.00	0.75	0.77	0.98	0.57	0.63	0.89
2097	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2098	0.73	1.00	0.73	0.72	1.00	0.72	0.74	1.00	0.74	0.68	0.88	0.76
2099	1.00	1.00	1.00	0.73	0.88	0.83	0.76	0.90	0.84	0.71	1.00	0.71
Mean (all industries)	**0.74**	**0.83**	**0.89**	**0.75**	**0.85**	**0.89**	**0.75**	**0.84**	**0.90**	**0.67**	**0.82**	**0.83**

Table 3. Average Annual Rate of Productivity and Efficiency Change in U.S. Food Industry, 1960-94 (percent)

Industry	Efficiency Change	Technical Change	Pure Efficiency Change	Scale Efficiency Change	Malmquist TFP Change
	EFFCH	TECHCH	PECH	SCCH	TFP
2011	1.000	1.011	1.000	1.000	1.011
2013	1.005	1.004	1.010	0.995	1.009
2015	1.026	0.994	1.023	1.003	1.020
2021	1.004	1.016	1.005	1.000	1.020
2022	1.000	1.003	1.000	1.000	1.003
2023	0.992	1.013	0.997	0.995	1.005
2024	0.993	1.016	1.001	0.993	1.009
2026	0.996	1.018	0.996	1.000	1.014
2032	0.993	1.012	0.999	0.994	1.005
2033	0.999	1.011	1.004	0.996	1.010
2034	1.000	1.010	0.998	1.002	1.010
2035	1.004	1.011	1.010	0.995	1.015
2037	0.996	1.005	1.006	0.990	1.001
2038	1.007	1.011	1.016	0.991	1.018
2041	1.000	1.014	1.003	0.997	1.015
2043	1.002	1.006	1.000	1.002	1.008
2044	0.994	1.009	0.992	1.001	1.003
2045	0.997	1.010	0.992	1.005	1.007
2046	0.996	1.009	0.996	1.000	1.005
2047	1.006	1.010	1.009	0.997	1.016
2048	1.001	1.018	1.008	0.993	1.019
2051	1.001	0.998	0.999	1.001	0.999
2052	0.992	1.001	0.997	0.995	0.993
2053	1.011	1.005	1.000	1.012	1.016
2061	1.005	1.008	1.000	1.005	1.013
2062	1.002	1.017	1.002	1.000	1.018

Table 3. Continued

Industry	Efficiency Change	Technical Change	Pure Efficiency Change	Scale Efficiency Change	Malmquist TFP Change
	EFFCH	**TECHCH**	**PECH**	**SCCH**	**TFP**
2063	1.002	1.013	1.001	1.001	1.015
2064	0.994	1.002	1.001	0.993	0.995
2066	0.985	1.010	0.985	1.000	0.995
2068	1.005	1.006	1.007	0.998	1.010
2074	0.991	1.011	0.999	0.991	1.001
2075	1.003	1.025	1.002	1.001	1.028
2076	0.993	1.011	1.000	0.993	1.003
2077	1.003	1.011	1.004	0.999	1.014
2079	0.995	1.016	0.994	1.000	1.010
2082	1.014	1.012	1.014	1.000	1.027
2083	1.008	1.015	1.002	1.006	1.023
2084	1.000	1.014	0.990	1.010	1.014
2085	1.014	1.013	1.011	1.003	1.027
2086	1.011	1.004	1.000	1.011	1.015
2087	1.003	1.019	1.000	1.003	1.023
2091	0.993	1.010	0.996	0.998	1.004
2092	0.999	1.004	0.999	1.000	1.003
2095	1.001	1.012	0.999	1.002	1.013
2096	1.001	1.011	1.006	0.995	1.012
2097	1.000	1.017	1.000	1.000	1.018
2098	0.998	1.010	0.991	1.007	1.008
2099	0.999	1.006	1.008	0.991	1.004
Mean (all industry)	**1.001**	**1.010**	**1.001**	**0.999**	**1.011**

Table 4. Productivity, Efficiency and Technical Change by Decade: U.S. Food Manufacturing Industries

Industry	Technical Change (TECHCH)				Technical Efficiency Change (EFFCH)				Malmquist TFP Change			
	1961-70	71-80	81-90	91-94	1961-70	71-80	81-90	91-94	1961-70	71-80	81-90	91-94
2011	1.000	1.000	1.000	1.000	1.010	1.014	1.002	1.029	1.010	1.014	1.002	1.029
2013	1.004	1.014	1.013	0.963	1.004	1.009	0.992	1.026	1.008	1.024	1.004	0.988
2015	1.028	1.031	1.037	0.981	0.992	0.984	0.995	1.023	1.020	1.015	1.031	1.004
2021	1.001	1.015	1.000	1.000	1.006	1.011	1.029	1.019	1.007	1.026	1.029	1.019
2022	1.002	1.000	1.000	0.993	1.002	1.007	1.007	0.989	1.004	1.007	1.008	0.982
2023	1.000	0.996	0.996	0.950	0.996	1.012	1.019	1.044	0.996	1.008	1.015	0.992
2024	0.985	1.005	0.999	0.973	1.010	1.008	1.014	1.051	0.995	1.013	1.013	1.023
2026	1.000	1.011	0.981	0.989	1.010	1.016	1.029	1.012	1.010	1.028	1.010	1.001
2032	1.000	1.003	0.982	0.977	1.009	1.000	1.023	1.024	1.009	1.004	1.005	1.001
2033	1.006	1.005	0.999	0.967	1.002	0.998	1.024	1.034	1.008	1.003	1.023	1.001
2034	1.019	1.002	0.991	0.973	1.006	1.003	1.015	1.022	1.025	1.005	1.007	0.993
2035	1.006	1.003	1.014	0.981	1.002	1.025	0.999	1.031	1.007	1.028	1.013	1.011
2037	1.005	1.008	0.971	1.006	1.001	0.988	1.019	1.029	1.005	0.996	0.989	1.035
2038	1.022	1.012	0.990	0.998	1.001	0.996	1.022	1.045	1.023	1.008	1.012	1.043
2041	0.989	1.018	0.997	0.993	1.012	1.012	1.009	1.042	1.001	1.031	1.005	1.034
2043	1.000	1.000	1.002	1.012	1.002	0.997	1.021	0.998	1.002	0.997	1.023	1.010
2044	1.000	0.985	1.003	0.978	0.997	0.999	1.026	1.023	0.997	0.983	1.029	1.001
2045	1.007	1.020	0.981	0.959	1.000	1.022	0.999	1.034	1.007	1.042	0.980	0.991
2046	0.999	1.007	0.984	0.992	1.013	1.006	1.017	0.988	1.012	1.013	1.000	0.980
2047	1.002	1.029	1.000	0.971	1.012	1.006	1.011	1.012	1.014	1.035	1.011	0.983
2048	0.991	1.018	1.003	0.980	1.013	1.006	1.026	1.037	1.004	1.025	1.028	1.016
2051	1.016	0.997	0.996	0.981	0.982	1.008	0.999	1.012	0.998	1.005	0.995	0.993
2052	1.015	0.998	0.964	0.993	0.978	0.993	1.024	1.022	0.993	0.991	0.987	1.015
2053	1.034	1.016	0.985	1.011	0.990	0.988	1.019	1.054	1.024	1.003	1.004	1.065
2061	1.003	1.025	0.990	1.002	1.005	0.999	1.013	1.022	1.008	1.024	1.003	1.024
2062	1.007	0.999	0.989	1.030	1.007	1.011	1.044	0.990	1.013	1.009	1.032	1.019
2063	0.993	1.001	1.018	0.985	1.002	1.005	1.029	1.022	0.995	1.006	1.047	1.006
2064	1.016	0.993	0.975	0.986	0.971	1.016	1.010	1.022	0.986	1.009	0.985	1.008

Table 4. Continued

Industry	Technical Change (TECHCH)				Technical Efficiency Change (EFFCH)				Malmquist TFP Change			
	1961-70	**71-80**	**81-90**	**91-94**	**1961-70**	**71-80**	**81-90**	**91-94**	**1961-70**	**71-80**	**81-90**	**91-94**
2066	0.974	1.004	0.991	0.955	1.011	1.005	1.006	1.030	0.985	1.008	0.997	0.984
2068	1.011	1.018	1.000	0.968	1.011	1.002	0.990	1.045	1.021	1.020	0.990	1.012
2074	1.002	0.990	0.988	0.971	1.008	1.002	1.021	1.014	1.011	0.992	1.008	0.984
2075	1.009	1.002	1.000	1.000	1.026	1.017	1.041	1.002	1.036	1.020	1.041	1.002
2076	0.988	0.998	1.014	0.941	1.002	1.010	1.027	0.994	0.990	1.007	1.042	0.936
2077	1.001	0.979	1.028	1.005	1.011	1.006	1.012	1.022	1.012	0.986	1.040	1.026
2079	0.979	1.012	0.982	1.023	1.005	1.011	1.035	1.009	0.984	1.023	1.016	1.032
2082	1.024	1.021	0.996	1.020	1.012	1.012	1.024	0.986	1.036	1.033	1.020	1.006
2083	1.023	0.981	1.005	1.047	1.020	1.007	1.029	0.987	1.044	0.987	1.034	1.033
2084	1.002	1.007	0.988	1.011	1.019	1.015	1.017	0.990	1.021	1.022	1.006	1.001
2085	1.024	1.032	0.985	1.017	1.008	1.002	1.029	1.012	1.033	1.034	1.014	1.029
2086	1.006	1.008	1.003	1.053	0.985	1.022	1.012	0.985	0.991	1.029	1.015	1.038
2087	1.011	1.000	1.000	1.000	1.021	1.024	1.015	1.016	1.032	1.024	1.015	1.016
2091	1.006	0.993	0.976	1.008	0.988	1.006	1.025	1.043	0.993	0.999	1.000	1.051
2092	1.000	1.000	0.999	0.992	1.002	0.995	1.007	1.022	1.002	0.995	1.005	1.014
2095	1.000	1.001	0.995	1.018	1.008	1.007	1.032	0.988	1.008	1.008	1.026	1.006
2096	0.995	0.995	1.000	1.033	0.999	1.001	1.021	1.041	0.994	0.997	1.022	1.075
2097	1.000	1.000	1.007	0.984	1.038	0.989	1.031	1.004	1.038	0.989	1.038	0.988
2098	0.999	1.002	1.001	0.983	0.999	0.997	1.024	1.032	0.998	0.999	1.025	1.014
2099	0.997	1.011	0.993	0.991	1.003	0.994	1.013	1.023	0.999	1.005	1.006	1.014
Mean (all industry)	**1.004**	**1.005**	**0.996**	**0.992**	**1.004**	**1.005**	**1.018**	**1.019**	**1.008**	**1.011**	**1.013**	**1.011**

Table 5. Cumulated Productivity and Efficiency Change in the U.S. Food Manufacturing Industries, 1960-94 (percent)

Industry	Efficiency Change (EFFCH)	Technical Change (TECHCH)	Pure Efficiency Change (PECH)	Scale Change (SCCH)	Malmquist Index (M_0)
2011	1.00	1.46	1.00	1.00	1.46
2013	1.17	1.16	1.39	0.85	1.36
2015	2.39	0.82	2.17	1.10	1.95
2021	1.16	1.69	1.17	1.00	1.97
2022	1.00	1.12	1.00	1.00	1.12
2023	0.75	1.55	0.89	0.85	1.17
2024	0.80	1.69	1.02	0.78	1.35
2026	0.88	1.83	0.87	1.01	1.61
2032	0.79	1.52	0.97	0.81	1.20
2033	0.97	1.44	1.13	0.86	1.40
2034	1.01	1.39	0.93	1.09	1.41
2035	1.16	1.46	1.39	0.83	1.69
2037	0.86	1.20	1.22	0.70	1.03
2038	1.26	1.44	1.73	0.73	1.81
2041	1.01	1.63	1.10	0.92	1.64
2043	1.07	1.21	1.00	1.07	1.29
2044	0.80	1.36	0.77	1.05	1.09
2045	0.90	1.41	0.76	1.18	1.28
2046	0.86	1.36	0.87	1.00	1.18
2047	1.21	1.40	1.35	0.90	1.69
2048	1.03	1.81	1.31	0.79	1.87
2051	1.02	0.94	0.97	1.05	0.95
2052	0.77	1.02	0.90	0.86	0.79
2053	1.47	1.19	0.99	1.48	1.74
2061	1.20	1.29	1.01	1.19	1.55
2062	1.06	1.75	1.06	1.00	1.86
2063	1.06	1.55	1.04	1.02	1.64
2064	0.81	1.05	1.02	0.79	0.85
2066	0.60	1.40	0.59	1.01	0.84

Table 5. Continued

SIC	Efficiency Change (EFFCH)	Technical Change (TECHCH)	Pure Efficiency Change (PECH)	Scale Change (SCCH)	Malmquist Index (MALM)
2068	1.17	1.22	1.26	0.93	1.42
2074	0.73	1.45	0.98	0.74	1.05
2075	1.12	2.32	1.08	1.04	2.60
2076	0.78	1.44	1.00	0.78	1.12
2077	1.10	1.45	1.14	0.97	1.60
2079	0.83	1.71	0.83	1.01	1.42
2082	1.61	1.51	1.61	1.00	2.43
2083	1.31	1.65	1.07	1.22	2.15
2084	1.01	1.60	0.72	1.41	1.63
2085	1.60	1.55	1.46	1.10	2.48
2086	1.46	1.13	1.00	1.46	1.64
2087	1.11	1.92	1.00	1.11	2.14
2091	0.80	1.41	0.87	0.92	1.13
2092	0.95	1.14	0.97	0.98	1.09
2095	1.03	1.51	0.95	1.08	1.56
2096	1.04	1.45	1.24	0.84	1.51
2097	1.01	1.79	1.00	1.01	1.81
2098	0.95	1.38	0.74	1.28	1.31
2099	0.96	1.21	1.30	0.74	1.16
Mean (all industry)	**1.02**	**1.41**	**1.05**	**0.97**	**1.44**

Appendix Table 1. List of U.S. Food Manufacturing Industries Included in the Analysis

SIC CODE	Industry Description
2011	Meat packing plants
2013	Sausages and other prepared meats
2015	Poultry slaughtering and processing
2021	Creamery butter
2022	Cheese, natural and processed
2023	Dry, condensed, and evaporated dairy products
2024	Ice cream and frozen desserts
2026	Fluid milk
2032	Canned Specialty
2033	Canned fruits and Vegetables
2034	Dehydrated Fruits, vegetables and soups
2035	Pickles, sauces and salad dressing
2037	Frozen fruits and vegetables
2038	Frozen specialties, n.e.c.
2041	Flour and other grain mill products
2043	Cereal breakfast foods
2044	Rice milling
2045	Prepared flour mixes and doughs
2046	Wet corn milling
2047	Dog and cat food
2048	Prepared feeds, n.e.c.
2051	Bread, cake, and related products
2052	Cookies and crackers
2053	Frozen bakery products, except bread
2061	Raw cane sugar
2062	Cane sugar refining
2063	Beet sugar
2064	Candy and other confectionary products and industry
2067	Chewing gum
2066	Chocolate and cocoa products
2068	Salted and roasted nuts and seeds
2074	Cottonseed oil mills
2075	Soybean oil mills
2076	Vegetable oil mills, n.e.c.
2077	Animal and marine fats and oils
2079	Edible fats and oils, n.e.c.
2082	Malt beverages
2083	Malt
2084	Wines, brandy, and brandy spirits
2085	Distilled and blended liquors
2086	Bottled and canned soft drinks
2087	Flavoring extracts and syrups, n.e.c.
2091	Canned and cured fish and seafoods
2092	Fresh or frozen prepared fish
2095	Roasted coffee
2096	Potato chips and similar snacks
2097	Manufactured ice
2098	Macaroni and spaghetti
2099	Food preparations, n.e.c.

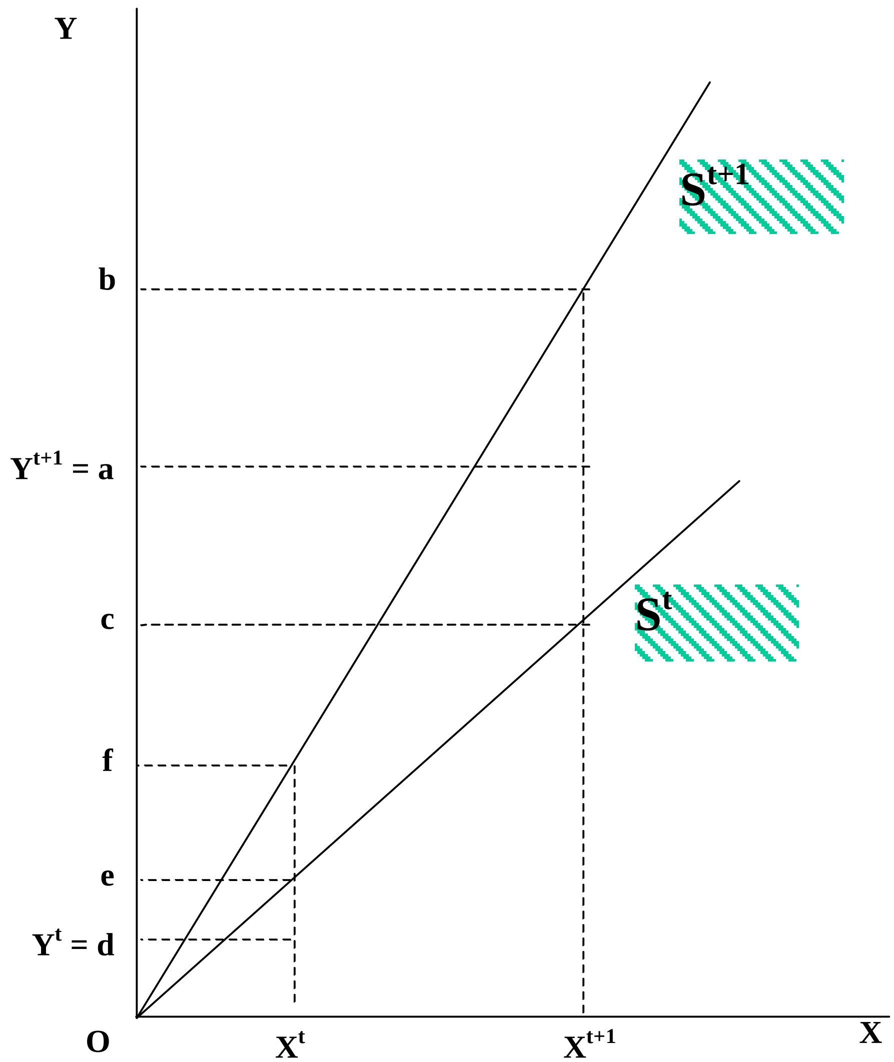

Figure 1. Malmquist Output-Based TFP Index

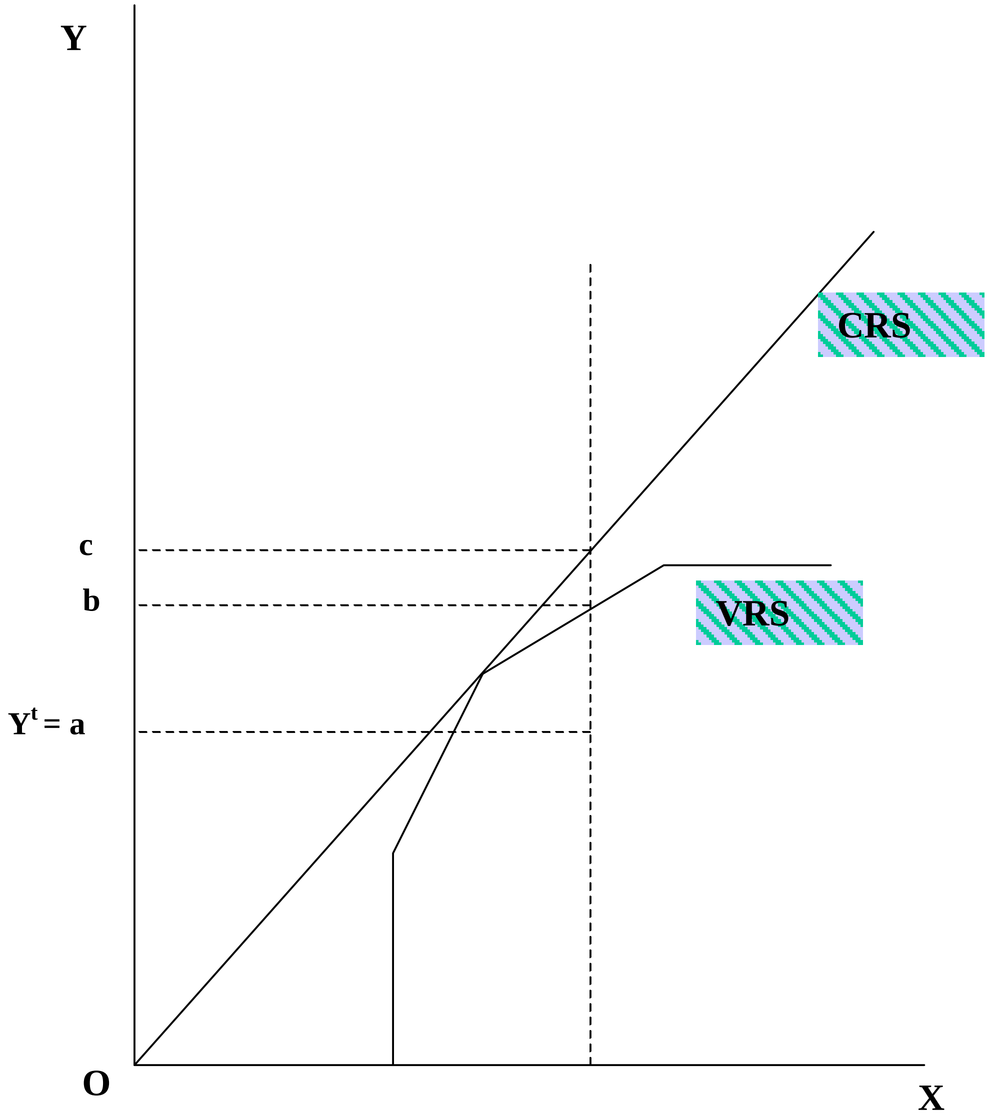

Figure 2. CRS and VRS and Scale Efficiency